1 Experimental Setup

An application related to machining tool condition was selected for the experiment. Tool condition is an important factor in the machining process.

Image of tools and a flank tool wear is shown in Figure 1.

Figure 1. Cutters and Tools and a flank tool wear at cutting edge

Most computer numerical control milling machines are not able to detect machining tool's wear in an on-line manner. The cutting force signal is instead used to establish usable models due to its high sensitivity to tool wear, low noise, and good measurement accuracy. In the experiment, a milling machine is used as the test bed. The schematic diagram of the experimental setup is illustrated in Figure 2.

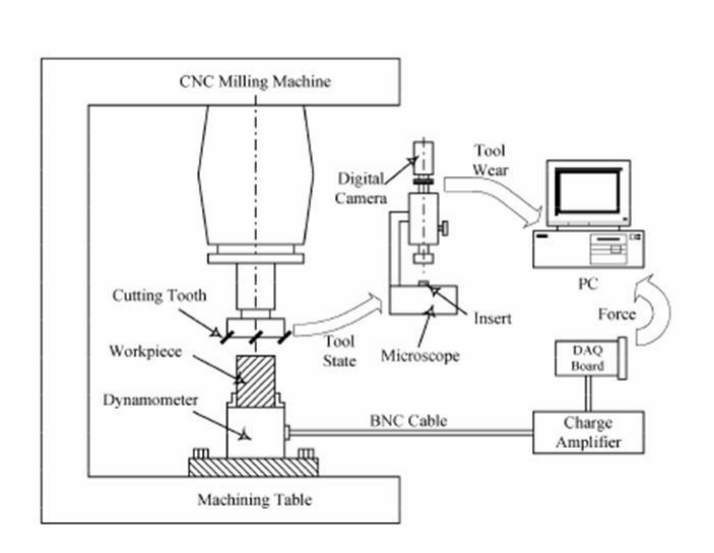

Figure 2. Experimental setup in machinery

The components of the experimental setup are listed in Table 1.

Table 1. Experimental Components

Components
Makino CNC milling machine with Funuc controller
EGD 4450R cutter with AC325
ASSAB718HH workpiece
Kistler 9265B Quartz 3-Component Dynamometer
Kistler 5019A Multi-channel Charge Amplifier
NI-DAQ PCI 1200 Board
Olympus microscope and Panasonic digital camera
Computer with P3 600MHz and 128M SDRAM

The cutting force along the y-direction of the machine was captured by the Kistler dynamometer in the form of charges, and converted to voltages by the Kistler charge amplifier. The voltage signal was sampled by the PCI 1200 board at 2000 Hz and directly streamed to the hard disk of the computer. The flank wear of each individual tooth was measured by the Olympus microscope, and at each time an average was taken from all the teeth mounted on the cutter. The tool state was observed by a Panasonic digital camera. Five experiments are included in this data folder. The cutting conditions examples are listed in Table 2. Experiment n & n_1 are using the same setup.

Table 2. Cutting Experiments

Test No	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Insert Number
1 & 1_1	1000	100	1	4
2 & 2_1	1000	200	1	2
3 & 3_1	1200	150	1	2
4 & 4_1	1000	100	1	4

2 Feature Extraction

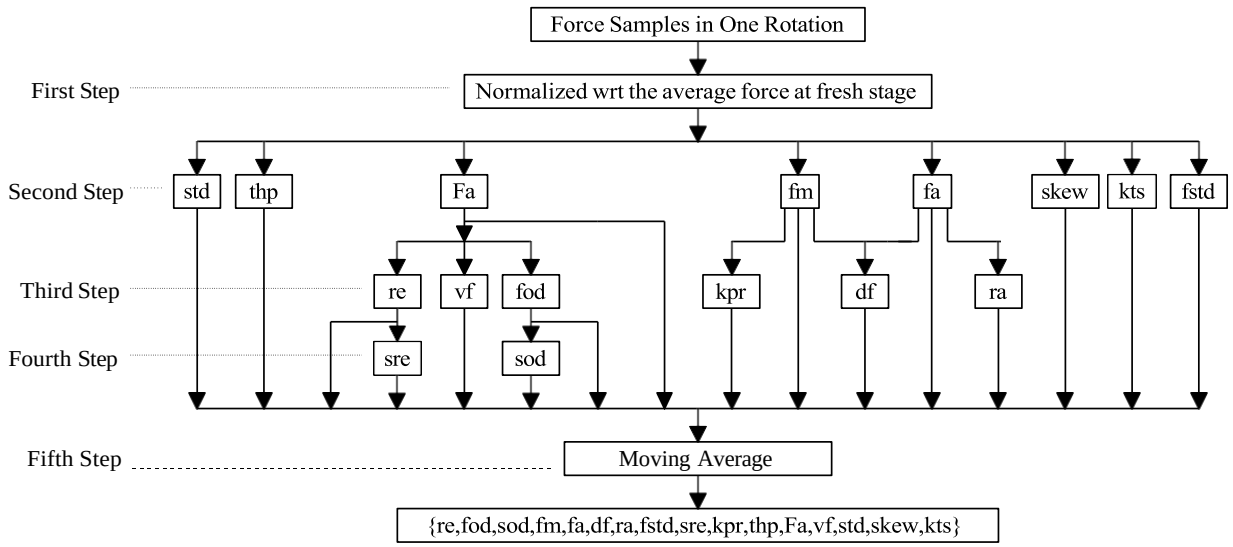

Figure 3. Features Extraction Procedures.

The feature extraction for the 16 features is carried out based on the procedures in Figure 3. Seven features are identified as relevant to tool wear: {*fm, fa, ra, fstd, Fa, std, kts*}, which are marked with blue color in the following table. Four of them could be recommended for tool wear estimation: {*fm, fa, Fa, std*}, simply because of the less computing cost and easiness in online implementation.

Table 3. Feature Extraction Methodologies

No	Feature	Notation
1	Residual Error	re
2	First Order Differencing	fod
3	Second Order Differencing	sod
4	Maximum Force Level	fm
5	Total Amplitude of Cutting Force	fa
6	Combined Incremental Force Changes	df
7	Amplitude Ratio	ra
8	Standard Deviation of the Force Components in Tool Breakage Zone	fstd
9	Sum of the Squares of Residual Errors	sre
10	Peak Rate of Cutting Forces	kpr
11	Total Harmonic Power	thp
12	Average Force	Fa
13	Variable Force	vf
14	Standard Deviation	std
15	Skew	skew
16	Kurtosis	kts

The 16 features are stored in the files with the corresponding names listed in Table 3.